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OPTICAL TRANSMISSION SYSTEM
[HIKARIDENSO HOSHIKI]

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[Claims] /*

[Claim 1] An optical transmission method,

being an optical transmission method which converts a frequency multiplication transmission signal multiplexed in a prescribed frequency range to light with a prescribed wavelength for transmission,

wherein the frequency range of said transmission signal is converted so that the intermodulation secondary distortion due to the sum frequency is converted upward to a higher range than the transmission range, while the intermodulation secondary distortion due to the difference frequency is converted downward to a lower range than the transmission range.

[Claim 2] An optical transmission method which converts frequency multiplication transmission signals multiplexed in a prescribed frequency range to light with a wavelength different from the zero-dispersion wavelength of the optical fiber cable,

wherein the sender side has a frequency converter means which converts the frequency range of said transmission signal so that the intermodulation secondary distortion due to the sum frequency is converted upward to a higher range than the transmission range and

intermodulation secondary distortion due to the difference frequency is converted downward to a lower range than transmission range, and

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* Claim and paragraph numbers correspond to those in the foreign text.

also has a wave-filtering means which removes output signals on the low frequency side among the frequency-converted output signals;

while the receiver side has a first wave filtering means that removes signals of the intermodulation secondary distortion component due to the difference frequency among intermodulation secondary distortion generated in signals that were converted up on the sender side for transmission,

a frequency converter means which converts the frequency range of the output signal from said first wave filtering means to the frequency range of the original transmission signal, and

a second wave-filtering means which removes the output signal on the high frequency side among the frequency-converted output signals.

[Detailed description of the invention]

[0001] [Field of Industrial Application]

This invention relates to an optical transmission method wherein the light of a specific wavelength is transmitted, via an optical fiber cable that does not generate dispersion distortion, by the light of wavelength λ_0 which is different from the specific wavelength. Here, specific a wavelength that does not generate dispersion distortion is called a zero-dispersion wavelength λ_C.

[0002] [Prior Art]

Optical fiber cables currently provided to the subscriber district has zero-dispersion wavelength λ_C equal to 1.3 μm (Hereafter, this optical fiber cable is referred to as "Optical fiber cable for

1.3 μm.”), and the wavelength of the light being transmitted is also 1.3 μm. On the other hand, there is an increasing demand for ways to transmit light with wavelength λ_0 other than the zero-dispersion wavelength (1.55 μm, for example) via the existing optical fiber cable for 1.3 μm in order to accommodate a wavelength multiplication method which aims to increase transmission capacity by multiplexing a plurality of light wavelengths.

[0003] Further, a technique to convert electric signals of multi-channel image signals that were frequency multiplexed into a light signal for transmission, for example, has become popular. However, when this light signal (wavelength λ_0)is transmitted via the existing optical fiber cable by multiplexing the frequency with light having a zero-dispersion wavelength of λ_C, it is known that the quality of transmission is degraded due to intermodulation secondary distortion. This intermodulation secondary distortion is considered to occur because of transmitting light with wavelengths other than the zero-dispersion wavelength of the optical fiber cable. However, study of its cause is an issue for the future.

[0004] Figure 3 shows that when a 1.55 μm optical signal which is electric optically converted from an AM-FDM (Amplitude Modulation - Frequency Division Multiplex) signal, whose required CSO (Composite Second Order) condition is more severe than an FM-FDM (Frequency Modulation-Frequency Division Multiplex) signal, is transmitted via an optical fiber cable for 1.3 μm, the intermodulation secondary

distortion is generated and CSO degrades as the transmission distance gets longer (M. Shigematsu et al., "Field test of multichannel AM-VSB transmission using erbium doped optical fiber amplifier at 1.55 μm wavelength range in the CATV network." OSA/IEEE, Topical Meeting on Optical Amplifiers and their Application, WB3, Monterey, Aug. 1990).

[0005] The AM-FDM signal used by conventional coaxial CATV service is in the 90 MHz ~ 468 MHz frequency range. Intermodulation secondary distortion that is generated when the electric signal in this range is converted to an optical signal with wavelength λ_0 which is different from the zero-dispersion wavelength of λ_C for transmission, using Figure 4 as a reference. In Figure 4, f_1~f_{60} show the carrier for each channel that is frequency multiplexed (frequency interval between each channel is not necessarily the same).

[0006] In Figure 4(1), intermodulation secondary distortion $f_{18}+f_{19}$ (392.5 MHz) generated by carrier f_{18} (193.25 MHz) and carrier f_{19} (199.25 MHz) is generated in the side band of carrier f_{50} (391.25 MHz). Further, in Figure 4(2), intermodulation secondary distortion $f_{16}-f_1$ (92 MHz) generated by carrier f_1 (91.25 MHz) and carrier f_{16} (183.25 MHz) is generated in the side band of carrier f_1 (91.25 MHz).

[0007] [Problems to be Resolved by the Invention]

In this manner, when light with a wavelength of λ_0 is transmitted using an optical fiber cable whose zero-dispersion wavelength is λ_C, intermodulation secondary distortion is generated. Therefore, if the light with a wavelength of λ_0 is the one that was electric optically

converted from an AM-FDM signal in the frequency range that is used by a coaxial CATV, for example, as shown in Figure 4(3), intermodulation secondary distortion would be generated by various carriers in the transmission range.

[0008] Namely, the range of intermodulation secondary distortion by the carrier difference frequency f_n-f_m (1) is 6 MHz (f_2-f_1) ~ 354 MHz ($f_{60}-f_1$), while the range of intermodulation secondary distortion by the carrier sum frequency (2) is 188.5 MHz (f_1+f_2) ~ 884.5 MHz ($f_{59}+f_{60}$), which implies that either one of these intermodulation secondary distortions is being generated in the transmission range used by the coaxial CATV.

[0009] Thus, the transmission signal in the prescribed frequency range is converted to light with a wavelength of λ_0, and is transmitted using an optical fiber cable whose zero-dispersion wavelength is λ_C; as can be seen from the CSO degradation property shown in Figure 3, it is difficult to transit over a long distance. This invention aims to provide an optical transmission method that transmits light of wavelength λ_0 using an optical fiber cable whose zero-dispersion wavelength is λ_C that can avoid degradation of the quality of the signal due to intermodulation secondary distortion.

[0010] [Means of Solving the Problems]

The invention according to Claim 1 is an optical transmission method which converts a frequency multiplex transmission signal multiplexed in a prescribed frequency range to light with a

prescribed wavelength for transmission, wherein the frequency range of said transmission signal is converted so that the intermodulation secondary distortion due to the sum frequency is converted upward to a higher range than the transmission range, while intermodulation secondary distortion due to the difference frequency is converted downward to a lower range than the transmission range.

[0011] The invention according to Claim 2 is an optical transmission method which converts frequency multiplication transmission signals multiplexed in a prescribed frequency range to light with a wavelength different from the zero-dispersion wavelength of the optical fiber cable, wherein the sender side has a frequency converter means which converts the frequency range of said transmission signal so that the intermodulation secondary distortion due to the sum frequency is converted upward to a higher range than the transmission range and intermodulation secondary distortion due to difference frequency is converted downward to a lower range than the transmission range, and also has a wave filtering means which removes output signals on the low frequency side among the frequency-converted output signals; while the receiver side has a first wave-filtering means that removes signals of the intermodulation secondary distortion component due to the difference frequency among the intermodulation secondary distortion generated in signals that were converted up on the sender side for transmission, a frequency converter means which converts the frequency range of output signal

from said first wave filtering means to a frequency range of original transmission signals, and a second wave-filtering means which removes an output signal on the high frequency side among the frequency-converted output signals.

[0012] [Working the Invention]

When transmission signals multiplexed in a prescribed frequency range are converted into light with a wavelength of λ_0, and are transmitted using an optical fiber cable whose zero-dispersion wavelength is λ_C, this invention converts up the frequency range of the transmission signals so that the generated intermodulation secondary distortion is outside of the transmission range, thereby making it possible to transmit without being influenced by the intermodulation secondary distortion.

[0013] Further, on the receiving side, since the frequency range of the transmission signal and the frequency range of the intermodulation secondary distortion are separated, it is possible to convert down to the original frequency range after eliminating the frequency range of the intermodulation secondary distortion, thereby making it possible to obtain a transmission signal that is completely free from influence by intermodulation secondary distortion.

[0014] [Embodiment]

Figure 1 is a block diagram showing the embodiment composition of the system that realizes this invention method. In this embodiment, we explain the case in which signals multiplexed in the frequency

range (90 MHz ~ 468 MHz), used by coaxial CATV service shown in Figure 4, are being transmitted.

[0015] In this figure, the frequency multiplexed transmission signal 'a' is inputted into multiplexer 11, and multiplexed with signal 'b' with a frequency of 400 MHz coming out from signal generator 12, and becomes modulated signal 'c.' The signal 'c,' after its high frequency component signal (490 MHz ~ 868 MHz) 'd' is extracted by a high-pass filter 13, is inputted into an electric-optic converter (E/O) 15.

[0016] The electric-optic converter 15 converts the signal 'd' into 1.55 µm analog optical signal 'e,' and irradiates it to an optical fiber cable with a zero-dispersion wavelength of 1.3 µm. The optical signal 'e' transmitted by optical fiber cable 21 is irradiated into optic-electric converter (O/E) 31 to be converted into an electric signal, turning into signal 'f' whose low frequency side of intermodulation secondary distortion was removed by high-pass filter 32. The signal 'f' is inputted into multiplexer 33, and multiplexed with signal 'g' with a frequency of 400 MHz coming out from signal generator 34, and becomes modulated signal 'h.' The signal 'h' goes through a low-pass filter 35 to become signal 'i' of its low frequency component (90 MHz ~ 468 MHz), and is retrieved as transmission signal 'a' via amplifier 36.

[0017] Behavior of this embodiment is explained next using Figure 2 as reference. In the transmission signal 'a' are signals of

carriers f_1 ~ f_{60} that have been frequency multiplexed. Here, as was explained in Figure 4, intermodulation secondary distortion is generated by signals having sum (f_n+f_m) and a difference (f_n-f_m) of two carrier frequencies in the transmission range. Here, the minimum value of intermodulation secondary distortion is f_1+f_2, while the maximum value of intermodulation secondary distortion is $f_{60}-f_1$.

[0018] Thus, under this embodiment, over the entire transmission range, signals are up-converted so that intermodulation secondary distortion f_1+f_2 due to carrier f_1 and carrier f_2 is converted to a higher range than the transmission range, while intermodulation secondary distortion $f_{60}-f_1$ due to carrier f_1 and f_{60} is converted to a lower range than the transmission range, using a multiplexer 11, a signal generator 12, a high-pass filter 13, and an amplifier 14; and the signal is converted to an optical signal and transmitted. The gap between the transmission range and the minimum value of sum frequency or the maximum value of difference frequency would be set with sufficient guard range so that sufficient filtering characteristics for frequency isolation are obtained, and at the same time, so that it is possible to avoid influence of group delay distortion of transmission signal.

[0019] In this embodiment, the frequency range of up-converted signal 'd' is set to 490 MHz ~ 868 MHz so that the intermodulation secondary distortion from f_n+f_m is higher than 988.5 MHz, while the intermodulation secondary modulation from f_n-f_m is lower than 354 MHz.

In this way, there is sufficient guard range between the transmission range to avoid overlapping. Thus, even when 1.55 µm analog optical signal 'e' is transmitted via an optical fiber cable with zero-dispersion wavelength of 1.3 µm, the transmission signal 'a' is not influenced by intermodulation secondary distortion since the intermodulation secondary distortion is outside of the transmission range.

[0020] Further, on the receiving side, the received optical signal is converted to an electric signal, then intermodulation secondary distortion $f_n - f_m$ is removed by high-pass filter 32, and the original transmission signal 'a' is extracted by converting down to the original frequency range of 90 MHz ~ 468 MHz using a multiplexer 33, a signal generator 34, a low-pass filter 35, and an amplifier 36. Thus, even when intermodulation secondary distortion is generated on the transmission route (optical fiber cable 21), the transmission signal 'a' that is extracted on the receiving side is completely free of such influence.

[0021] Although a frequency range of 90 MHz ~ 468 MHz was converted up by a single multiplexer, it is possible that the intermodulation secondary distortion generated in the range could become substantial if only one multiplexer 11 is used, as shown in the embodiment in Figure 1. In such a case, it is possible to realize similar frequency conversions under this invention by dividing the frequency range of 90 MHz ~ 468 MHz into a plurality of ranges, and

execute an upward converting process for each of the divided range (for each octave, for example). In case of downward conversion, even if a single multiplexer 33 is used for the process, the influence of intermodulation secondary distortion that is generated in the range can be ignored, compared to upward conversion.

[0022] [Advantageous Effects of the Invention]

As explained above under this invention, when the transmission signal that was frequency multiplexed in a prescribed frequency range is transmitted by converting the signal into an optical signal with a wavelength that is different from the zero-dispersion wavelength of the optical fiber cable, it is possible to separate the transmission range and the range of intermodulation secondary distortion occurrence by converting up the frequency range of the transmission signal.

[0023] Thus it is possible to avoid the influence of intermodulation secondary distortion of the transmission signal. And, even when light with wavelengths other than the zero-dispersion wavelength is transmitted by a frequency multiplexing method, it is possible to realize high-quality and long-distance optical transmission.

[Brief Description of the Figures]

[Figure 1] A block diagram showing the embodiment composition of the system that realizes this invention's method.

[Figure 2] A diagram showing the relationship among the frequency

range of upward conversion time, the carrier of each channel, and the intermodulation secondary distortion.

[Figure 3] A diagram showing the relationship between the length of the optical fiber and the CSO when the optical signal with a wavelength of 1.55 μm (AM-FDM signal) is transmitted via an optical fiber cable for 1.3 μm.

[Figure 4] A diagram showing the relationship among the frequency range of conventional transmission signal, the carrier of each channel, and the intermodulation secondary distortion.

[Explanation of Codes]

11 … Multiplexer;

12 … Signal generator;

13 … High-pass filter;

14 … Amplifier;

15 … Electric-optic converter (E/O)

21 … Optical fiber cable;

31 … Optic-electric converter (O/E)

32 … High-pass filter;

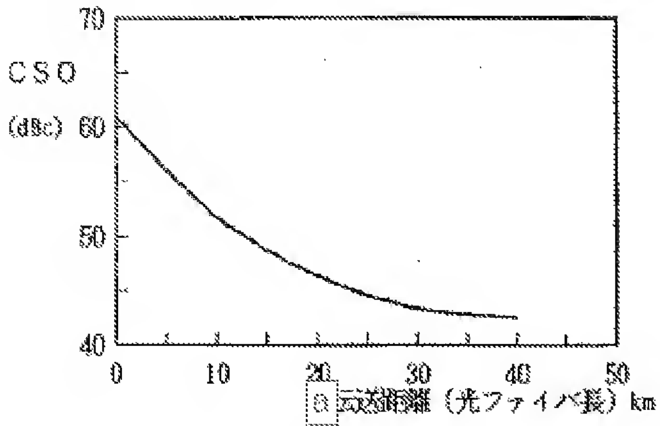
33 … Multiplexer;

34 … Signal generator;

35 … Low-pass filter;

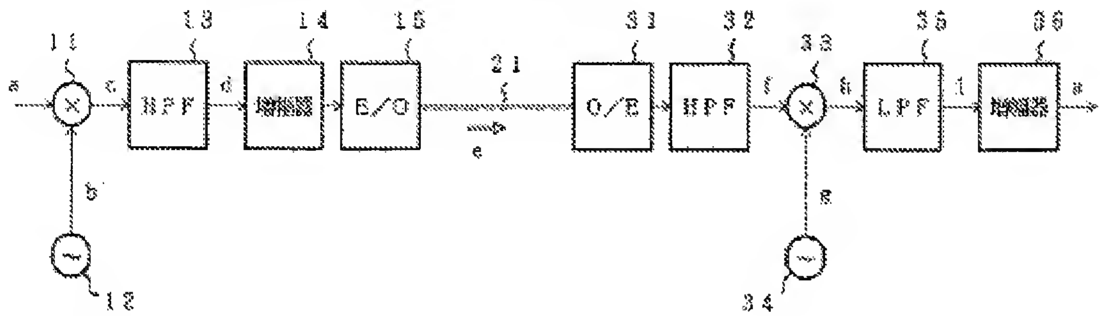
36 … Amplifier;

[Figure 3] CMOS characteristics



Key: a) Transmission distance (length of optical fiber) km

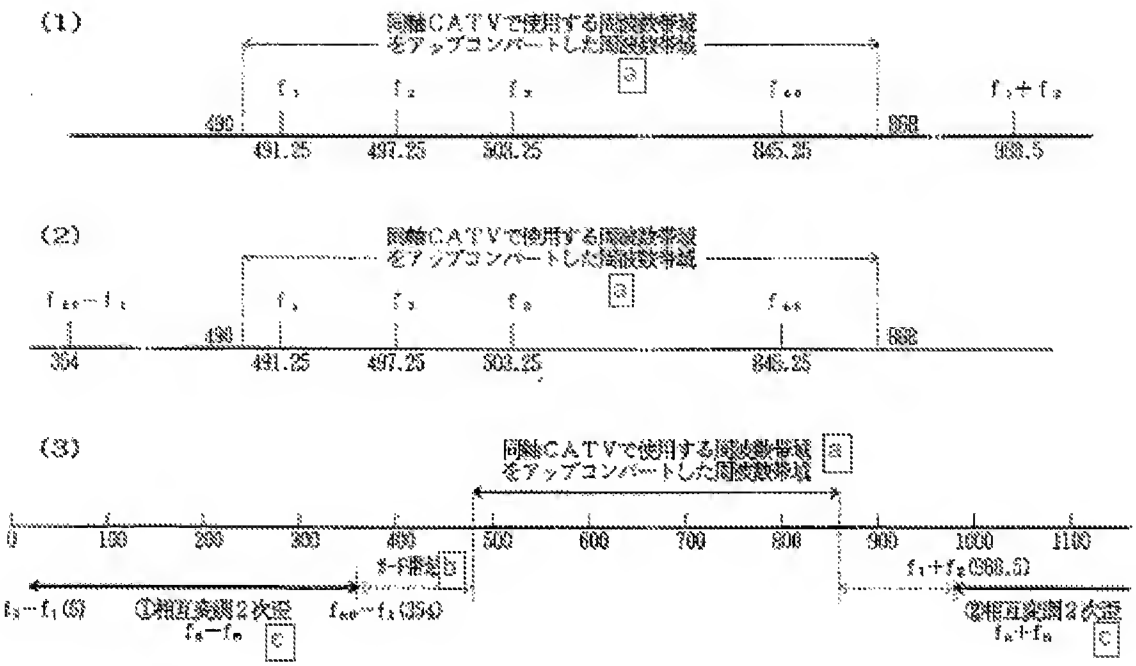
[Figure 1] A block diagram showing an embodiment of the system that realizes this invention /5



14- Amplifier
36- Amplifier

/6

[Figure 2] Relationship among the frequency range of upward conversion time, the carrier of each channel, and the intermodulation secondary distortion.



Key:

a) Frequency range obtained by converting up the frequency range used in coaxial CATV

b) Guard range

c) Intermodulation secondary distortion

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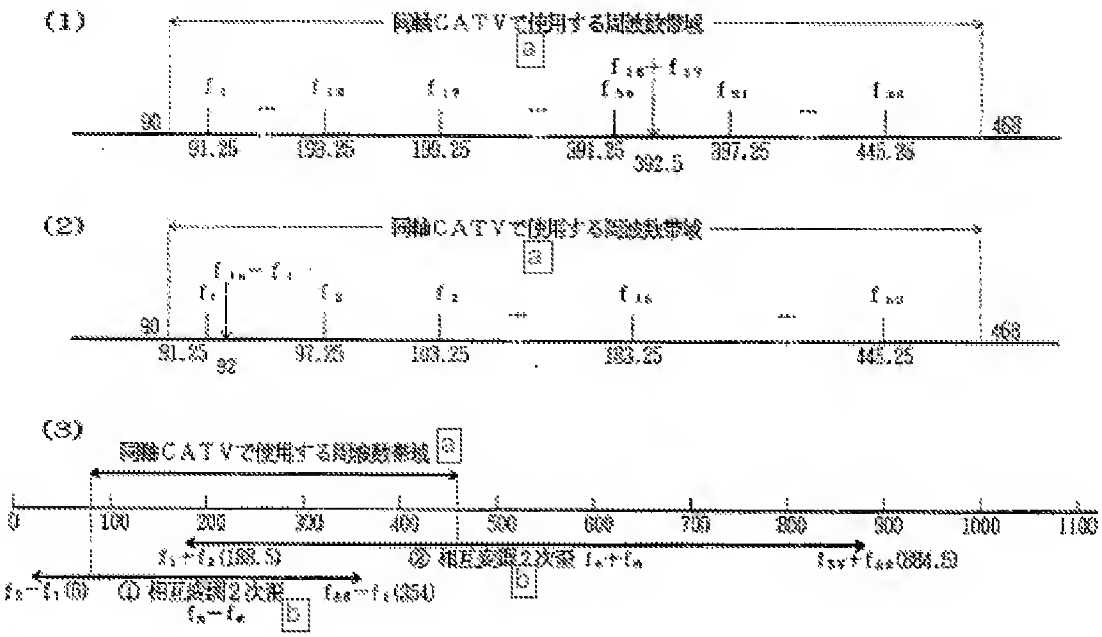
[Figure 4] Relationship among the conventional frequency range, the carrier of each channel, and the intermodulation secondary distortion.



Key:
a) Frequency range used in coaxial CATV
b) Intermodulation secondary distortion